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AIR TEMPERATURE AND WIND PROFILES IN AN ALASKAN LOWLAND BLACK SPRUCE STAND

by

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ABSTRACT

Temperature and wind profiles were investigated in an Alaskan lowland black spruce stand. Results indicate windspeeds measured 14.8 feet (4.5 meters) above the canopy are over four times faster than those measured at 1.6 feet (0.5 m) above the ground vegetation. Temperature measurements indicated a persistent positive lapse rate between 11.5 and 14.8 feet (3.5-4.5 m). Inversions were apparently more persistent at 0 to 4.9 feet (0-1.5 m) above the ground, regardless of solar energy input.

KEYWORDS: Temperature, windflow, black spruce, *Picea mariana,* Alaska, vegetation, fire behavior (forest), fire control.

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INTRODUCTION

Interior Alaska has vast areas of lowland black spruce (*Picea mariana* (Mill.) B.S.P.). The trees and associated vegetation are distributed in unique mosaic patterns. These patterns reflect the wildfire activity common to this portion of the State. Numerous cities, towns, and villages exist in the interior. Increasing populations find developments in the wild lands adjacent to these communities desirable. A fire management program is necessary to assist land managers and to develop and protect natural resources, human life, and property.

Black spruce sites usually appear to have sparse vegetation with spindly trees. Closer examination reveals substantial fine fuel accumulations, sometimes in excess of 50 tons per acre (112.09 metric tons per hectare). During warm, dry summers these fine fuels can become extremely hazardous. Forest fire management efforts depend not only on knowledge of the fuel's physical characteristics and the diurnal fluctuations in fuel moisture, but also on the wind profiles within the forest stands.

Fuel moisture fluctuations are a function of numerous interrelated factors. Two principal factors are energy and vapor exchanges. Energy is required for the evaporation of water. The water vapor transport phenomenon occurs along partial pressure gradients of water vapor. Field studies often attempt to characterize the energy exchange from measurements of air temperature gradients. Vapor pressure gradients are difficult to measure, and wind profiles are often used to help describe the transport characteristics of vapor and energy.

With knowledge of the influence of vegetative cover on air temperature and wind profiles, forest fire managers can more accurately predict potential fire behavior and rate of fire spread.

The objective of this study was to investigate air temperature and wind profiles in a stand of lowland black spruce.

STUDY AREA

The Bonanza Creek Experimental Forest is 14 air miles (22.5 kilometers) west-southwest of Fairbanks, Alaska. It is at 148°15' W. longitude and 65°45' N. latitude. Elevations range from 550 to 1,650 feet (168-503 m). This typical lowland black spruce stand is on the Tanana River flood plain at a 550-foot (168-m) elevation. The 51-year-old trees average 9.4 feet (2.9 m) in height and 1.05 inches (2.7 centimeters) in diameter at breast height. Stand basal area is 82 square feet per acre (18.8 m^2/ha) with 11,067 stems per acre (27,374 stems/ha). Stand biomass is estimated to be 64.65 tons per acre (144.93 metric tons/ha) (Barney and Van Cleve 1973). This biomass is distributed as follows: moss, 84.5 percent; black spruce trees, 11.1 percent; dead and down material, 1.8 percent; standing dead material, 1.6 percent; and herbaceous vegetation, 1.0 percent.

METHODS

Data were collected at one sampling location in the black spruce stand during the summer of 1972. Instruments were supported on a tower with

horizontal members at these levels (fig. 1A):

Level	Height Feet	Height Meters
1	1.6	0.5
2	4.9	1.5
3	11.5	3.5
4	14.8	4.5

The 11.5-foot (3.5-m) level approximated the maximum crown height.

Air temperature sensors consisted of Yellow-Springs[2] thermistors mounted in aluminum radiation shields (Barney 1972). Wind measurements were obtained from modified Freize Airways anemometers that provided a contact closure for each one-twelfth mile of wind passage. These anemometers have a starting threshold windspeed of approximately 2 miles per hour (3.22 km/h). One thermistor and one anemometer were located at each level. Two battery operated Rustrak recorders with dual charts were used. Wind and temperature data from each level were recorded continuously on half the dual chart (fig. 1B).

Data were transcribed at 15-minute intervals. Wind run[3] measurements were summed over the 15-minute period before each recording of temperatures at the sampling location.

Figure 1.--A, view of tower and instruments; B, recording instruments adjacent to tower.

[2] The use of trade, firm, or corporation names is for the information and convenience of the reader. Such use does not constitute official endorsement or approval by the U.S. Department of Agriculture.

[3] Wind run is the total accumulation of miles of wind over time.

The data from 1 overcast day (September 3, 1972) and from 2 clear days (August 30 and September 5, 1972) were analyzed. Data were complete at all levels for these days, and sky conditions were either uniformly overcast or clear.

RESULTS AND DISCUSSION

Air Temperature

Diurnal air temperature variability was less during overcast conditions (fig. 2) than during clear sky conditions (figs. 3 and 4) because of less intense solar radiation and minimized sensible heat generation on the overcast day. Furthermore, cloud cover diffused radiation and distributed the energy more uniformly within the open black spruce stand. Variability was lowest at the 14.8-foot (4.5-m) level. Air circulation at this level was less restricted because it was about 3 feet (1.0 m) above the general canopy level.

Temperature inversions persisted during the overcast day and one clear day (fig. 2 and fig. 4) between the 1.6- and 4.9-foot (0.5- and 1.5-m) levels. A dominant influence may be the substantial moist moss biomass. Approximately 0.38 inch (0.97 cm) of rain September 1 and a possible trace on September 4 may have substantially increased the heat sink potential of the moss. The cool, moist surface would favor shallow inversion development. On August 30 (fig. 3) the inversion was dissipated before 1200 hours, was reestablished between 1300 and 1500 hours, and was dissipated again from 1800 to 2200 hours. Two clear days preceded the clear day, August 30. Sufficient moisture deficit in the moss surface could result in ample sensible heat generation and destroy inversions on August 30.

Lapse rates at 4.9 to 11.5 feet (1.5-3.5 m) in the black spruce reflected active energy exchanges during all days. Both the overcast day (September 3) and one clear day (September 5) exhibited isothermal or positive lapse rates starting about 0900

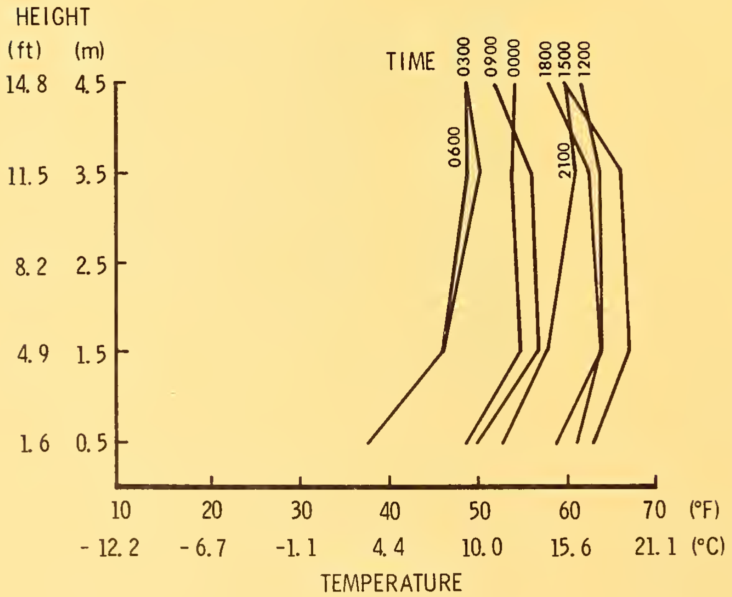

Figure 2.--Temperature profiles during an overcast day, September 3, 1972.

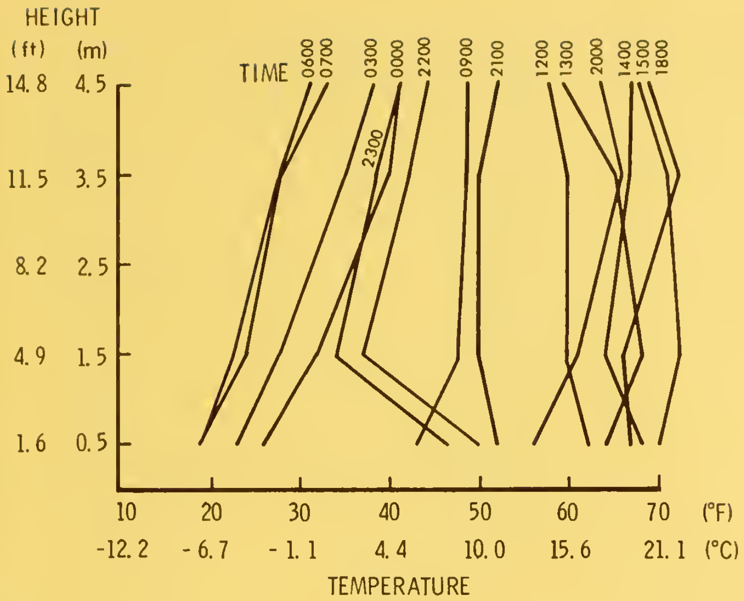

Figure 3.--Temperature profiles during a clear day, August 30, 1972.

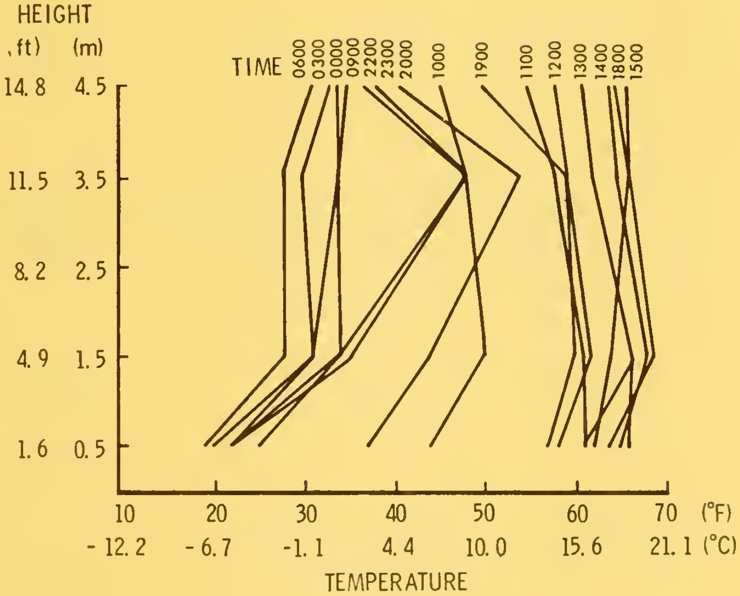

Figure 4.--Temperature profiles during a clear day, September 5, 1972.

hours. These conditions weakly persisted until 1800 to 2000 hours. On September 5 a strong 11°F (6.1°C) inversion developed at 2200 hours. A more complex situation of inversions, isothermals, and positive lapse rates occurred on August 30 throughout the afternoon.

Distinct temperature responses occurred above the black spruce canopy, 11.5 to 14.8 feet (3.5-4.5 m). Progressive warming

during the day indicated positive response by the vegetation to solar radiation. The nocturnal inversion was dissipated on or before 0900 hours. Positive lapse rates persisted after 1800 hours; and on September 5, a strong lapse rate developed from 1900 hours to the end of the day. The persistent positive lapse rates between 11.5 and 14.8 feet (3.5 and 4.5 m) may indicate the thermal storage of the black spruce stand.

Wind

Interior Alaska generally experiences, on the average, minimal wind activity. The massive Alaska Range to the south and southwest of Fairbanks and the Brooks Range across the northern portion of the State shield the interior from much storm activity. Greatest average windspeeds occur from April through October with August and September having average speeds of 5.7 and 5.8 miles per hour (9.2 and 9.3 km/h), respectively, at instrument shelter heights (Searby 1968).

Capabilities for predicting forest fires for suppression efforts can be improved if relationships between free airflow above and beneath a canopy are developed. Windspeeds above a forest canopy may have a logarithmic profile (Munn 1966). Canopy structure dominates air movement within a stand. Tree height, crown geometry, tree spacing, and understory structure all influence air movement. These data indicate a general relationship between above and below canopy wind velocities for this study site. The fire spread prediction model (Rothermel 1972) considers the windspeed at mid-flame height one of the most essential input variables. Historically, weather for fire danger rating purposes is measured in a clearing and wind is measured at a 20-foot (6.1-m) standard or equivalent (Fischer and Hardy 1972). It is important, therefore, to know which conversion factor is appropriate for various cover types. The 20-foot (6.1-m) standard measurement must be extrapolated to an effective windspeed within the canopy. Because wind is an important variable in the prediction model, a more specific scaling for local canopies is desirable.

Differences in nocturnal and diurnal wind velocity are apparent from analysis of accumulated wind run over time (figs. 5, 6, and 7). Accumulated wind run was proportional to height above the ground surface. The overcast day (fig. 5) exhibited minimal and somewhat erratic wind activity. Wind run was slight from 0000 to 2100 hours and then increased. This increase may have been due to the passage of a large scale weather system.

In contrast, accumulated wind run data under clear sky conditions (figs. 6 and 7) exhibited a different distribution. Nocturnal, downslope winds and diurnal, thermal wind activity may have caused the slope changes in the graphs. If so, nocturnal, downslope winds of low speed were detected only at level 4--the roughness of the black spruce canopy would negate any influence within the stand. The elevation difference between the study site and an adjacent hilltop was 1,100 feet (335 m). These slight, erratic winds were evident from 0000 to 0900 hours on August 30 and from 0000 to 1000 hours on September 5. The approximated windspeeds would be

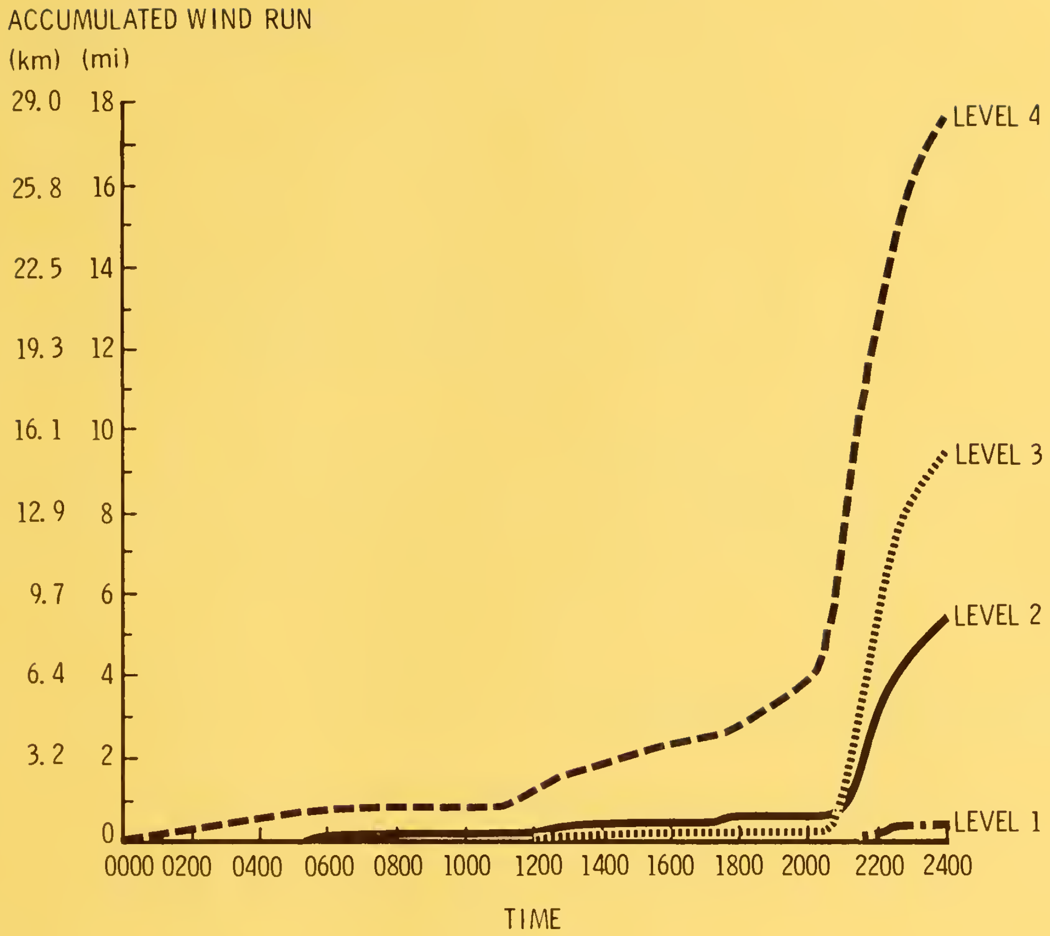

Figure 5.--Accumulated wind run at four levels on an overcast day (September 3, 1972) in a lowland black spruce stand.

0.17 and 0.08 mile per hour (0.27 and 0.13 km/h), respectively, averaged over the 9- and 10-hour periods. Sunrise occurred just before 0800 hours, after which time thermal responses were noted (figs. 3 and 4). The nocturnal winds continued for approximately 1 hour until diurnal, thermally activated winds dominated. Nocturnal, downslope winds began again at 2100 hours on August 30 and 1900 hours on September 5. The winds averaged 0.19 and 0.37 mile per hour (0.31 and 0.60 km/h), respectively (table 1).

Daytime windspeeds were substantially greater than the nocturnal winds as indicated by the steeper slopes of the accumulated wind run figures. Average diurnal and nocturnal

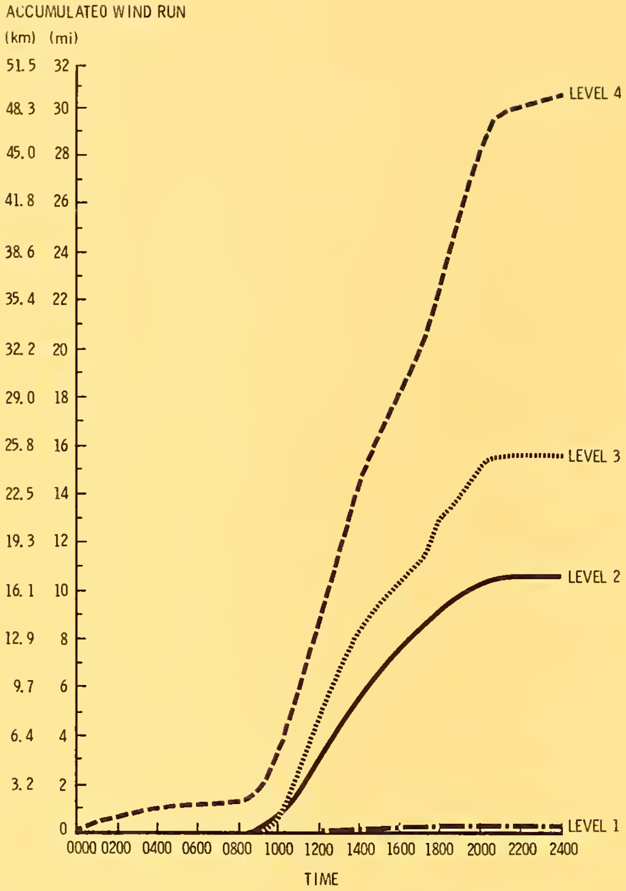

Figure 6.--Accumulated wind run at four levels on a clear day (August 30, 1972) in a lowland black spruce stand.

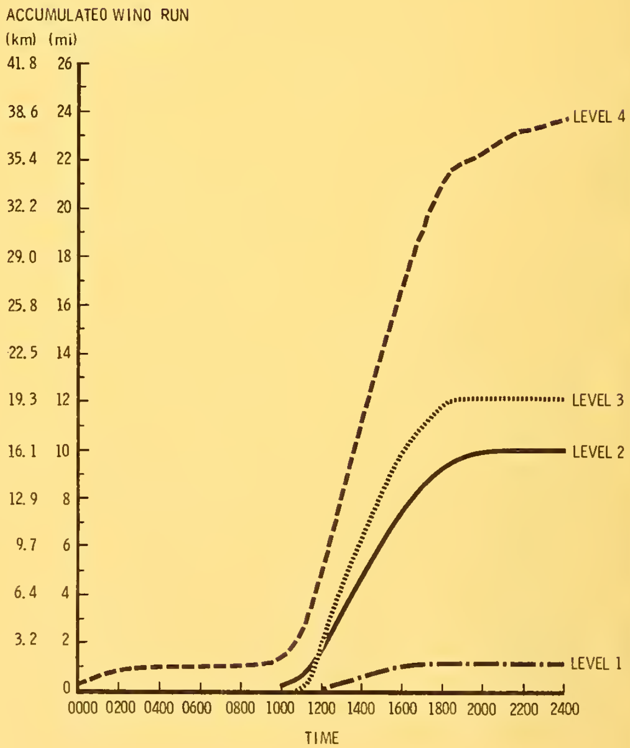

Figure 7.--Accumulated wind run at four levels on a clear day (September 5, 1972) in a lowland black spruce stand.

Table 1--*Average windspeeds for diurnal and nocturnal conditions at four levels on clear days, August 30 and September 5, 1972*

Level number and height of wind			August 30						September 5					
			Diurnal		Nocturnal				Diurnal		Nocturnal			
					a.m.		p.m.				a.m.		p.m.	
	ft	m	mi/h	km/h	mi/h	km/h	mi/h	km/h	mi/h	km/h	mi/h	km/h	mi/h	km/h
4	14.8	4.5	2.48	3.99	0.17	0.27	0.19	0.31	2.75	4.43	0.08	0.13	0.37	0.60
3	11.5	3.5	1.39	2.24	0	0	0	0	1.69	2.72	0	0	0	0
2	4.9	1.5	.95	1.53	0	0	0	0	1.26	2.03	0	0	0	0
1	1.6	.5	.03	.05	0	0	0	0	.19	.31	0	0	0	0

windspeeds per level are presented in table 1. Typically, speeds increase with height and are greatest above the canopy level.

The diurnal windspeeds relative to the level 4 data are illustrated in figure 8. Relative speeds increased markedly from 1.6 to 4.9 feet

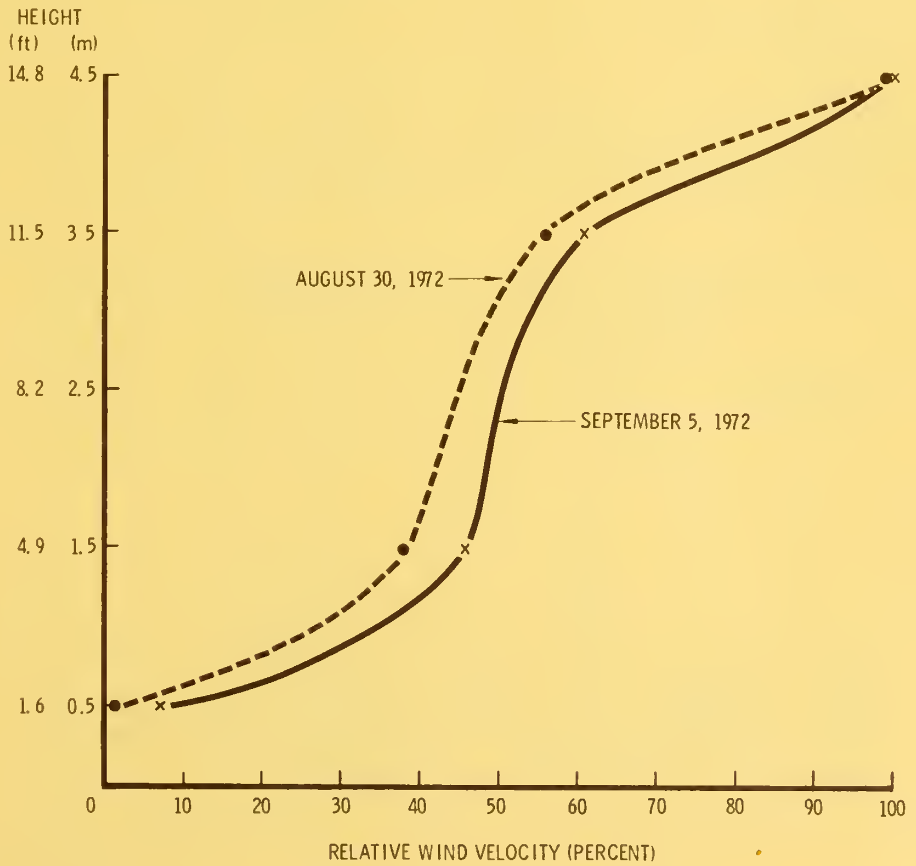

Figure 8.--Approximated relative windspeed on 2 clear days as a percent of windspeed at 14.8-foot (4.5-m) height.

(0.5-1.5 m). Between 4.9 and 11.5 feet (1.5 and 3.5 m), the black spruce crown zone, the relative speeds exhibited much less change. Above 11.5 feet (3.5 m), the top of the crown level, speeds increased rapidly in the free airspace.

Diurnal wind run at levels 1, 2, and 3 for the 2 clear days combined show linear relationships with that of level 4 (table 2). The slopes of the relationships decrease with height. Correlations such as these should enhance potential for predicting wind measurements for fire management purposes. These relationships were developed by eliminating observations when zero wind was observed at level 4.

CONCLUSIONS

Effective forest fire control programs are in need of research to assist in predicting rate of fire spread and fuel moisture relationships. Air temperature and wind variables are important indicators of the energy and water vapor transport phenomena interacting with the physical fuel system; they are also important in predicting spread and behavior of burning fires.

In the lowland black spruce study site, temperature inversions may persist for 1 or more days in the 0- to 4.9-foot (0- to 1.5-m) height surface layer irrespective of inputs of solar energy. This condition may be due to partial shading from the black spruce and the potential heat sink provided by the sizable moss-herbaceous ground cover. This ground cover comprises 84 percent of the stand's total biomass.

Temperatures in the black spruce crown zone, 4.9 to 11.5 feet (1.5-3.5 m) above the ground, indicated active energy exchange processes. Soon after sunrise, isothermal conditions and lapse rates dominated this zone. In-

Table 2--*Results of linear regression analyses comparing wind run data at levels 1, 2, and 3 (dependent variables) with wind run data at level 4 (independent variable)*

Level	n	r^2	a	b	Mean	SD
4	128	0	0	0	5.086	3.473
3	128	0.837	-0.975	0.703	2.602	2.669
2	128	.797	-.335	.4406	1.906	1.714
1	128	.149	-.0567	.0388	.141	.347

NOTE: Level 1 = 1.6 feet (0.5 m); level 2 = 4.9 feet (1.5 m); level 3 = 11.5 feet (3.5 m); level 4 = 14.8 feet (4.5 m); n = number of observations; r^2 = coefficient of determination; a = intercept; b = slope; SD = standard deviation; regression form is Y = a + bx.

versions recurred throughout the clear day of August 30 which indicated complexities unresolved by this study.

Above the black spruce canopy the inversions were dissipated soon after sunrise and lapse rates persisted several hours after sunset. This may indicate substantial thermal storage capacity in the small, dense crowns. Temperatures above the canopy were less erratic than at lower levels and increased with time during the day.

Wind relationships on overcast days may be dominated by large scale weather systems instead of stand conditions. The wind was light and erratic throughout the overcast day (September 3), but windspeed increased markedly after 2100 hours.

Distinct nocturnal and diurnal wind distributions are evident. Analyses of accumulated wind run over time on 2 clear days clearly distinguished between downslope, nocturnal winds and diurnal winds. Nocturnal winds averaged 0.08 to 0.37 mile per hour (0.13-0.60 km/h). They were only detected above the black spruce canopy. The winds ceased about 0900 hours and began about sunset (1900-2100 h).

Average diurnal windspeeds were greatest at the 14.8-foot (4.5-m) level. A substantial reduction occurred at the 11.5-foot (3.5-m)(top of the crown) to the 4.9-foot (1.5-m) level. Below the crown zone at 1.6 feet (0.5 m), winds averaged less than 0.5 mile per hour (0.8 km/h). Linear correlations relate windspeeds within the black spruce canopy.

The preceding information has provided some initial insights into temperature and wind profile relationships within a black spruce stand. The potential exists for developing fire effects models and precise predictions of fire behavior in the flammable lowland black spruce stands of interior Alaska. As fire management activities and decisions become more sophisiticated, the need for improved predictions will increase. The information from this study, however, will provide a first look and, we hope, will be one step toward gaining more sophisticated information in the future.

LITERATURE CITED

Barney, Richard J.
1972. An inexpensive meteorological radiation shield for thermistors and thermocouples. USDA For. Serv. Res. Note PNW-190, 7 p., illus. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Barney, Richard J., and Keith Van Cleve.
1973. Black spruce fuel weights and biomass in two interior Alaska stands. Can. J. For. 3(2):304-311.

Fischer, William C., and Charles E. Hardy.
1972. Fire weather observer handbook. USDA For. Serv. Intermt. For. and Range Exp. Stn., 152 p., illus. Ogden, Utah.

Munn, R. E.
1966. Descriptive micrometeorology. 245 p. Acad. Press, New York.

Rothermel, Richard C.
1972. A mathematical model for fire spread prediction in wildland fuels. USDA For. Serv. Res. Pap. INT-115. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Searby, Harold W.
1968. Climate along a pipeline from the Arctic to the Gulf of Alaska. U.S. Dep. Commer., Environ. Sci. Serv. Adm., Weather Bur., Tech. Memo. AR-2, 16 p.

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